HEREDITY OF HAIR-FORM IN MAN

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THE hair of man shows various morphological types. Between straight hair, on the one hand, and woolly hair, on the other, there are all degrees of closeness of spiral. For convenience three intermediate grades may be recognized; *wavy,* having a very slight or open spiral involving the entire hair from root to tip; *curly,* having a closer spiral involving the distal half of the hair; and *frizzy* or *kinky,* a close tight spiral of small diameter. Now, although the conditions thus named are not discontinuous, they stand for types that are fairly well appreciated and distinguished popularly, so that in a random lot of people practically all would place a given sort of hair in the same category.

These different types of hair form are associated with certain differences of the hair on cross section as well as in its method of growth. Thus straight hair is nearly circular on cross section, while in woolly hair the cross section is elliptical and the long axis is to the short as 100:40 or 100:50. In wavy hair the proportions are as 100:60 or 70. The straight hair of the Japanese has the proportions of 100:85.

Since the hair of most mammals is straight and nearly circular on cross section, we may regard this as the basal condition and the flattened hair as a specialized form marking an advance in the *differentiation* of axes. In addition to this difference in cross section hairs differ in the form of the hair follicle, which is in woolly hair not only flattened, but curved in an arc through a quarter of a circle. "Emerging from an incurvated mould, it can only

continue to roll up outside, given especially its flattened shape; it rolls up into a spiral the plane of which, at the beginning, is perpendicular to the surface of the skin'' (Deniker '06, p. 43). As all gradations exist between straight hair and wool in other characters, so probably in the initial curvature. The intermediate nature of *waviness* is probably due to an intermediate degree of curvature beneath the skin. This curvature of the follicle, again, is a departure from the usual mammalian condition and is in the line of differentiation or advance.

We are now in a position to formulate our problem. How do the more specialized types of hair form—much flattened and much curved woolly hair and slightly flattened, slightly curved wavy hair behave in heredity toward each other and toward the nearly cylindrical straight hair?

The data for this study are derived from the same sources as those of our eye color study[1] and include the ancestral characteristics of about 500 children for two ascending generations. About 230 families are involved.

The nomenclature of hair form that collaborators were requested to employ was as follows: Straight, wavy, curly, kinky. As our cards were distributed only among whites the term ''woolly'' was not used. The terms seem to have been, for the most part, understood by the collaborators.

The first result revealed by an analysis of the pedigree data regarding hair form is that straight hair is recessive to the curved types. Thus to 70 pairs of parents both said to have straight hair were born 185 children of which we have records. Of these 167 are recorded as having straight hair; 13 ''wavy'' and 5 ''curly.'' Also 164 grandparents, both with ''straight hair,'' are said to have had 146 straight-haired children, 11 ''wavy'' and 7 ''curly.'' Knowing how liable to slip collaborators are we venture to affirm that probably not less than 98 per cent. of the offspring of straight-haired parents have

[1] *Science*, N. S., XXVI, No. 670, pp. 589–592, November 1, 1907.

themselves straight hair.[2] The genuine cases of straight-haired parents producing wavy or curly hair in the children are probably cases of imperfect dominance—or heterozygotes in which the recessive type appears to dominate. In all such cases the grandparentage contains always one or more cases of wavy or curly hair. Cases of recessive heterozygotes are not rare in the experience of students of heredity. They do not invalidate the general idea of Mendelian dominance. Striking cases of all straight-haired offspring of straight-haired parents are seen in the Bal., Bea., Bri., But., Cla., Hof., Loe., Mil., Oat., Pot., Reg., Sam., Spr. and Whe. families, each of four or more children. In these families there are 63 children altogether, and all of them have straight hair.

A second criterion of Mendelism is found in crosses of the R $\times$ DR type where a recessive is mated to a heterozygous dominant; in this case expectation is fifty per cent. of each type. Eighty matings between straight and heterozygous wavy give 61 straight and 52 curved-haired offspring, and 22 matings between straight and curly give 53 straight and 38 curved; or altogether, 116 to 90 where 103 of each is expectation (Cf. Dou-B., Got., Halz., Kar., McBr. families). There is a slight excess of recessives, probably due in part to a tendency to designate as "straight" boys whose curly hair is cut short; possibly to some cases of failure to dominate.

A third criterion is found in the crosses of the DR $\times$ DR type where two heterozygotes are mated to-

[2] The principal sources of error in naming hair form made by our collaborators are as follows: (1) Citing in males the form of the short, clipped hair instead of the youthful *long hair*. Curly hair when cut short appears as straight hair; this source of error is great in the case of the grandfathers, who are frequently deceased; (2) recording a hair form from a hazy recollection; a slightly wavy hair is often recalled as "straight." An attempt was made to get a confirmation of all doubtful cases (*i. e.*, not in accordance with the law) and in almost all cases in which a reply was received one of the two "straight" parents of curved-haired children was found actually to have curved hair. One exceptional case is that of the Hil family, where three wavy haired children came from two straight haired parents. The mother probably has curly germ cells which fail to dominate.

gether. Expectation in this case is 25 per cent. of the straight hair and 75 per cent. of the curved types—of the later 25 per cent. being pure dominants (DD) and 50 per cent. DR. Of 59 offspring of two DR parents there were actually found 22 per cent. curly, 51 per cent. wavy and 27 per cent. straight, or 73 per cent. curved to 27 per cent. straight. This again accords closely with expectation and supports the view of the essential DR nature of wavy hair (Cf. Bar., Gav., Gen. families).

All results indicate with a high degree of probability that straight hair is recessive to spiral hair; but it is probable that the spiral form may, in some cases, fail to dominate.

We have now to consider the behavior of wavy in relation to curly or kinky, *i. e.*, the lesser grade toward the greater. The statistics show clearly that wavy hair is usually, if not always, a *heterozygous* condition, and not merely an intermediate stage that is recessive to a higher stage (curly) and dominant over a lower (straight). For straight by wavy frequently gives curly (10 per cent. of cases) as well as wavy and straight. The result is in close accord with the conclusion that wavy always carries both straight and curly germ cells and when mated with single yields in the offspring an equality of straight and curved hair. Thus 113 offspring of straight by wavy parents give 54 per cent. straight and 46 per cent. curved hair. The "curly" germ cell of a *wavy*-haired person, uniting with a "straight" germ cell, usually gives the heterozygous, wavy form; but in 23 per cent. of the cases fails to do so, owing, we may say, to the unusual activity of the curly determiner. Wavy appears also when the curly germ cells of a heterozygous *curly*-haired person unite with "straight" germ cells. As in the last case, the offspring are not all wavy; indeed, the proportion of wavy is less, for 53 per cent. of the offspring are *curly*. That peculiar strength which makes a heterozygote *curly* instead of wavy tends to make its heterozygous offspring also curly instead of wavy.

We can now formulate the results of this study in their relation to human marriage, combining them in part with those obtained by us for eye color. Two blue-eyed, straight-haired parents will have only blue-eyed, straight-haired children. Two wavy-haired parents may have straight, wavy- or curly-haired children but the chances for curly hair are slight. Two curly-haired parents may have children with either straight, wavy or curly hair and the proportion of curly-haired offspring will probably be large. When one parent has straight hair and the other curly hair the offspring will all have curly hair, if the curly-haired parent is homozygous—otherwise half of their children will have straight hair and half curved. But the families of straight and wavy haired parents will probably have straight as well as wavy and curly hair, for waviness is always heterozygous.

TABLE SHOWING INHERITANCE OF HAIR FORM IN ALL FAMILIES OF TWO OR MORE CHILDREN.

c, curly; s, straight; w, wavy; k, kinky. Letters in parentheses refer to *recessive* characters; when accompanied by a ? the recessive character is inferred. Brackets are employed to designate inferred gametic constitution. ?? implies doubt whether the assigned character is correct. — means no record.

Reference Letters.	Children. C	W	S	Parents. Mother. Father.	Nature of Mating.	Grandparents. Mother's Mother. Father's Mother.	Mother's Father. Father's Father.	Expectation. Curved.	Straight.	Remarks.
				s		s	s			
Bal			6	s	R × R	s	c(s?)		6	
				w[cs]		w[cs]	s			
Bar	3	2	1	c(s)	DR × DR	s	c	4.5	1.5	
				s		s	s			
Bea			5	s	R × R	—	s		5	
				w[cs]		c(s?)	w[cs]			Mother's sibs. :
Beh	1	6	1	s	DR × R	s	s	4	4	1 c, 1 w, 2 s.
				s		s	s			
Bri			5	s	R × R	s	s		5	
				s		s	s			
But			4	s	R × R	s	s		4	
				c(s)		s	c			
Byr	4	2		c	DR × D	w[cs]	c	6		
				s		s	s			
Cam	1	5	4	w[cs]	R × DR	s	s??	5	5	
				s		s	s			
Cla			4	s	R × R	s	s		4	
				s		s	c(s?)			
Dav			2	s	R × R	s	s		2	
				s		s	s			
Deg		1	1	c(s)	D × DR	w[cs]	s	1	1	
				s		w[cs]	s			
Dou-A		2	5	c(s)	R × DR	c	s	3.5	3.5	
				c(s)		w[cs]	c			
Dou-B	2		2	s	DR × R	w[cs]	s	2	2	
				w[cs]		s	s			
Dra	2			k	DR × D	c	c	2		
				s		w[cs]	c(s?)			
Dru			2	w[cs]	R × DR	w[cs]	—	1	1	
				s		s	w[cs]			
Elt	1	1	1	c(s)	R × DR	w[cs]	s	1.5	1.5	
				s		s	w[cs]			
Eny		1	8	w[cs]	R × DR	s	c	4.5	4.5	
				c(s)		c	s			
Fal		1	6	s	DR × R	s	s	3.5	3.5	
				w[cs]		w[cs]	c(s?)			Mother's sibs. :
Fis	2	1	1	s	DR × R	c(s)	s	2	2	2 w, 1 s.
				s		s	s			
Fri			3	s	R × R	s	s		3	
				s		s	s			
Fue			3	s	R × R	s	s		3	
				w[cs]		w[cs]	w[cs]			
Gav	2	4	1	w[cs]	DR × DR	w[cs]	w[cs]	5.3	1.7	
				c(s)		s	w[cs]			
Gen		2	1	w[cs]	DR × DR	s	c	2.3	0.7	
				c(s)		s	c			
Gla	2	1	4	c(s)	DR × DR	c	s	5.3	1.7	

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				w[cs]		s	c			
Gor	2	3	6	c(s)	DR × DR	w[cs]	c	8.2	2.8	
				s		c (s?)	s			
Got		2	2	w[cs]	R × DR	s	w[cs]	2	2	
				w[cs]		s	w[cs]			
Gre		2		w[cs]	DR × DR	w	w[cs]	1.5	0.5	
				w[cs]		w[cs]	s			
Hal_1	2	1	1	s	DR × R	s	w[cs]	2	2	
				s		s	s			
Hal_2	2		2	s??*	R × DR	c	s			*[Probably curly when grown long]
				c(s)		s	s??			
Har	3	1	6	s	DR × R	s	s	5	5	
				s		w[cs]	s			
Hil		3		s	?DR × R	s	s	1.5	1.5	
				s		s	c(s?)			
Hof			5	s	R × R	s	s		5	
				s		s	s			
Hop			2	s	R × R	s	s		2	
				w[cs]		s	c			
Huf		2	1	s	DR × R	w[cs]	s	1.5	1.5	
				w[cs]		s	c			
Hur		3	1	s	DR × R	s	c	2	2	
				s		s	c			
Irw_1			2	w[cs]	R × DR	s	w[cs]	1	1	
				w[cs]		—	—			
Irw_2		1	2	s	DR × R	—	—	1.5	1.5	
				w[cs]		s	s??			
Jem	2	1		s	DR × R	w	s	1.5	1.5	
				w[cs]		s	w[cs]			
Ker	1	1	2	s	DR × R	s	s	2	2	
				s		s	s			
Koc	1		4	s??*		w[cs]	s			*[Probably curly when grown long]
				c(s)		c	s			
Lat	4		1	s	DR × R	s	s	2.5	2.5	
				s		s	s			
Loc_1			5	c(s)	R × DR	c(s?)	c	2.5	2.5	
				w[cs]		c	w[cs]			
Loc_2			2	s	DR × R	s	c(s?)	1	1	
				s		s	c(s?)			
Loe			4	s	R × R	s	s		4	
				s		c	s			
McBr	2		3	c(s)	R × DR	s	c	2.5	2.5	
				s		c(s)	s			*[Probably curly when grown long]
Mea	1	2	1	s??*		c	s			
				s		s	s			
Mil_1			3	s	R × R	s	s		3	
				s		s	s			
Mil_2			6	s	R × R	s	s		6	

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				s		w[cs]	s			
Moo			2	c(s)	R × DR	s	s ??	1	1	
				s		s	c(s ?)			
Mor			2	w[cs]	R × DR	—	—	1	1	* 1 sister has curly hair.
				s*		s	s ?? ***			** s, in manhood, 1 sister has curly hair.
Mur-B	1		2	c(s)**	R × DR	s	s ?? ***	1.5	1.5	*** Recollection hazy.
				s		—	—			
Oat			8	s	R × R	—	—		8	
				w[cs]		w[cs]	w[cs]			
Pad		5		w[cs]	DR × DR	—	—	3.8	1.2	
				c(s)		s	s*			
Poe			3	s	DR × R	s	s	1.5	1.5	* Confirmed by letter.
				s		s	s			
Pot			4	c(s ?)	R × DR	c(s ?)	c	2	2	
				c(s)		c	w[cs]			
Pre	1	4	1	s	DR × R	w[cs]	s	3	3	
				s		w[cs]	s			
Rau			2	s	R × R	s	s		2	
				s		s	s			
Reg			6	w[cs]	R × DR	s	s	3	3	
				s		w[cs]	s			
Sam_1		1	1	c(s ?)	R × DR	c	c(s ?)	1	1	
				c(s)		w[cs]	s			
Sam_2		3	2	s	DR × R	s	s	2.5	2.5	
				s		s	s			
Sam_3			5	s	R × R	s	s		5	
				s		s	s			
Sco	1		5	s ??*		c	s			* [Probably curly when long.]
				s		s	s			
Sho			3	s	R × R	s	s		3	
				s		—	—			
Spr			4	s	R × R	—	—		4	
				s		s	s			
Sto-B			2	s	R × R	s	s		2	
				s		s	c(s ?)			
Swe			3	s	R × R	s	s		3	
				w[cs]		w[cs]	s			
Tru	1	1	2	s	DR × R	w[cs]	s	2	2	
				w[cs]		c	s			
Tuc	1	1		w[cs]	DR × DR	w[cs]	w[cs]	1.5	0.5	
				s		s	s			
Voo			3	s	R × R	s	s		3	
				w[cs]		c	w[cs]			
War-A	1	1		w[cs]	DR × DR	w[cs]	s	1.5	0.5	
				s		c(s ?)	s			
War-B			2	s	R × R	s	s		2	
				s ??		c(s)	s			
Web		2	5	s		s	s			

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				w[cs]		s	s?			
Wel		3	7	s	DR × R	—	c	5	5	
				s		s	s			
Wet			2	s	R × R	s	s		2	
				s		—	—			
Whe_1			6	s	R × R	—	—		6	
				c(s?)		—	—			
Whe_2		1	1	s	DR × R	s	s	1	1	
				s		s	s			
Wil_2			3	s	R × R	s	s		3	
				s		s	s			
Zim			2	s	R × R	s	s		2	
Total		110	202					123	189	